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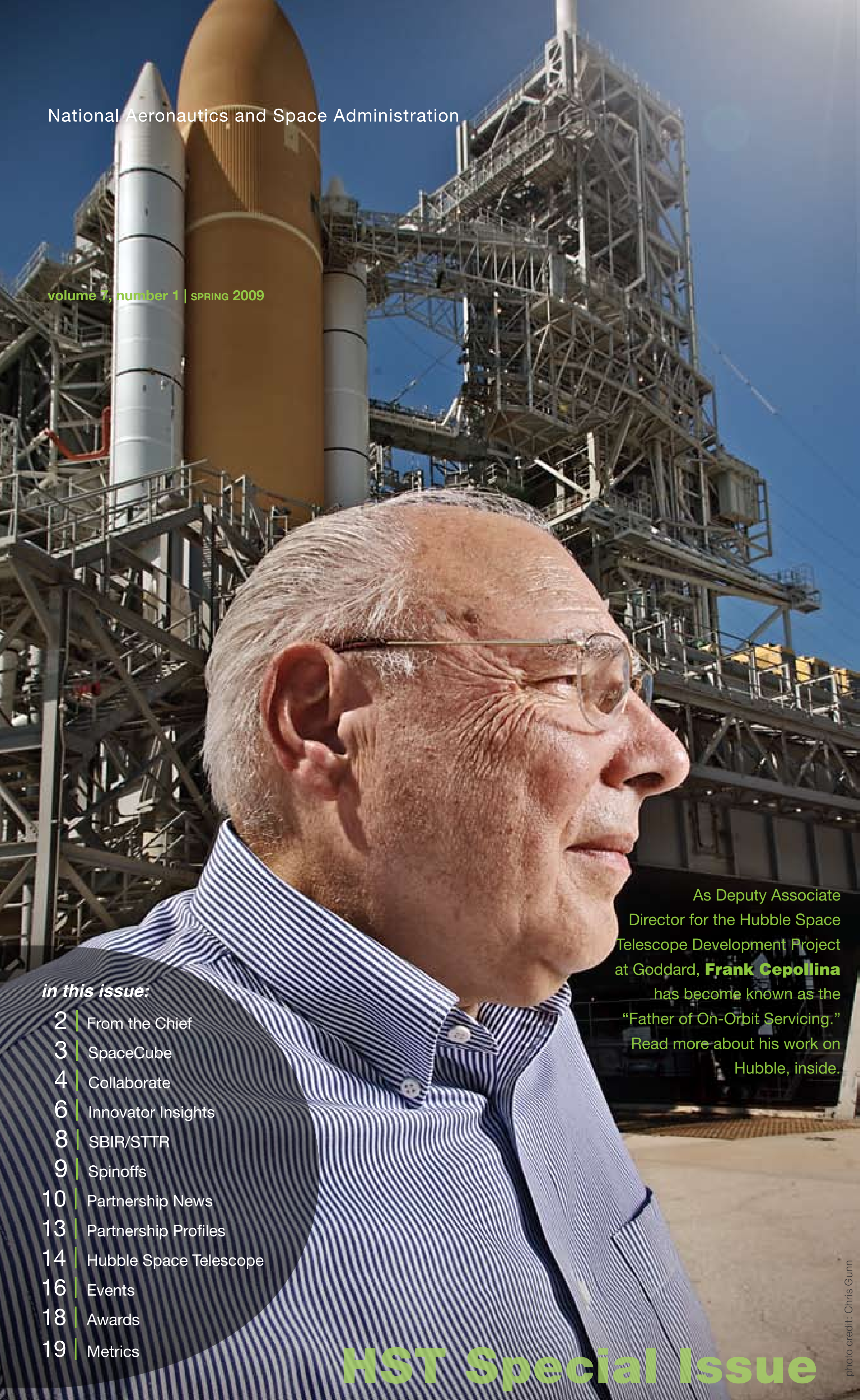


photo credit: Chris Gunn

As Deputy Associate Director for the Hubble Space Telescope Development Project at Goddard, **Frank Cepollina** has become known as the "Father of On-Orbit Servicing." Read more about his work on Hubble, inside.

in this issue:

HST Special Issue

from the chief

photo credit: Chris Gunn

STS 125 launch for SM4

Nona Cheeks

Thank you for picking up this special issue of *Goddard Tech Transfer News.* The Hubble Space Telescope (HST) is a key example of a mission that gives rise to many new technologies for NASA programs and projects, as well as many benefits beyond government use. Goddard has recently completed its latest mission to service HST, bringing the telescope's technology up to date with the latest and greatest advances available.

Advanced technology is what makes the remarkable science achieved by HST possible. The Innovative Partnerships Program reaches out to organizations beyond NASA to inform, learn, share, and leverage technology development and utilization. And, NASA collaboration with outside organizations and leading technology companies is an important part of what makes the technologies on HST a reality—bringing the best outside of NASA into our mission. In addition, many of the advanced technologies that help HST achieve great discoveries have found their way into cutting-edge products that can improve life here on Earth, through previous and ongoing technology spinoff efforts.

In this special issue dedicated to the technology and milestones of HST, Goddard's Innovative Partnerships Program Office salutes the collaboration and innovation that has made the recently completed servicing mission (SM4) a reality. We look forward to the potential for more technology infusion and spinoff as a result of this critical mission.

Enjoy!

Nona Cheeks
Chief, Innovative Partnerships Program Office (Code 504)
NASA's Goddard Space Flight Center ■

> "The Innovative Partnerships Program reaches out to organizations beyond NASA to inform, learn, share, and leverage technology development and utilization.
>
> — Nona Cheeks"

SpaceCube Offers More Processing Power—and Potential for Commercial Applications

spacecube

The recent SM4 included in its payload an advanced new reconfigurable processor for high-rate data systems called SpaceCube. Part of SM4's Relative Navigation Sensors (RNS) system, SpaceCube recorded imagery of HST as it came in for docking and as it was released. Controlling three cameras, a GPS receiver, a command and telemetry module, and 500 GB of memory, SpaceCube is the brain of the RNS. SpaceCube also hosted two real-time image processing and tracking algorithms capable of determining the exact position and attitude of HST.

According to David Petrick, processor lead engineer in the development of SpaceCube, capturing positional data with a high-speed processor is important because it helps NASA get closer to the goal of robotic servicing missions and makes better use of the available data coming into the system. "One big issue with current satellites is that they have lots of data coming in, but current processors can only make use of 10-20 percent of an instrument's bandwidth capability," said Petrick. "With SpaceCube, we can get closer to 100 percent usage of data because we can process it in real time, compress it, and send it back to Earth, increasing the amount of data we could be utilizing to make scientific breakthroughs. Current systems are just too slow to do that."

SM4 provided an opportunity to test this new processor, which is inexpensive to construct, small in size, and lightweight. "It's actually the most powerful, lightest piece of equipment in the shuttle bay," said Petrick. "So to have something that small and efficient demonstrate the capability to track HST during docking and deploy with great accuracy is a big step forward. So much of what we did with the RNS required a high-speed processor like SpaceCube. Other existing space processors wouldn't have gotten the job done."

In fact, Petrick said that SM4 was the first time a processor has been carried on board a servicing mission that would give engineers this type of data about where HST was located at a given time. "SM4 was an opportunity for a proof of concept, and we proved that

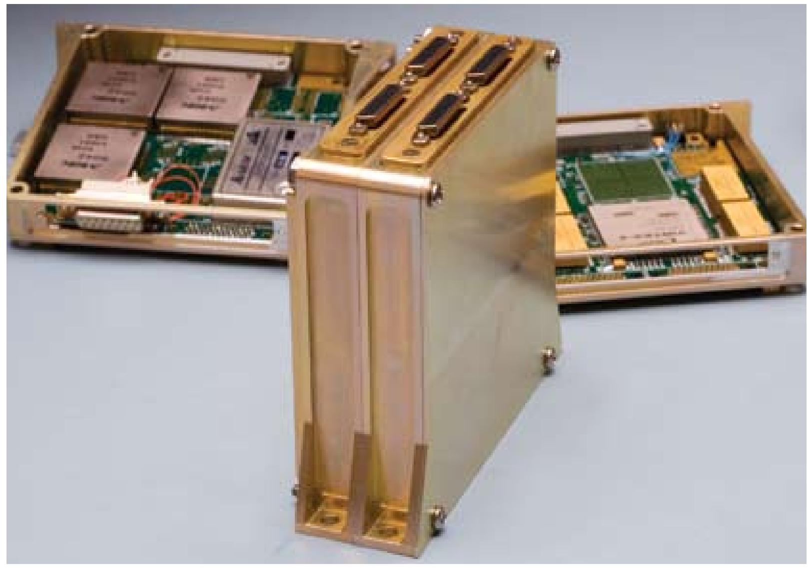


photo credit: Chris Gunn

The SpaceCube high-speed processor was the most powerful, lightest piece of equipment in the shuttle bay on the recent servicing mission.

SpaceCube is capable of handing a flight system with extreme data processing requirements. SpaceCube enabled RNS to complete all on-orbit objectives."

What's next for the technology? First, all of the data RNS recorded will be downloaded, analyzed, and processed over the next year to see what worked well and what areas need improvement. Petrick suggested the addition of a new sensor to give a better range estimation as well as optimizing the software algorithms. Then, making its second flight, SpaceCube will launch later this year to the International Space Station for a 2- to 5-year mission that will evaluate new radiation hardened by software mitigation techniques. These efforts will lead to SpaceCube 2.0, a new development under the charge of Goddard innovator Tom Flatley. According to Petrick, the next version of the processor will target longer-term missions, such as the Earth Science Decadal Survey missions, rather than shorter missions like SM4.

Further development of the processing technology should also lead to exciting commercial opportunities as well. Petrick said that the technology could be used in applications where there is a high quantity of data coming into a system and real-time on-board processing or data reduction is

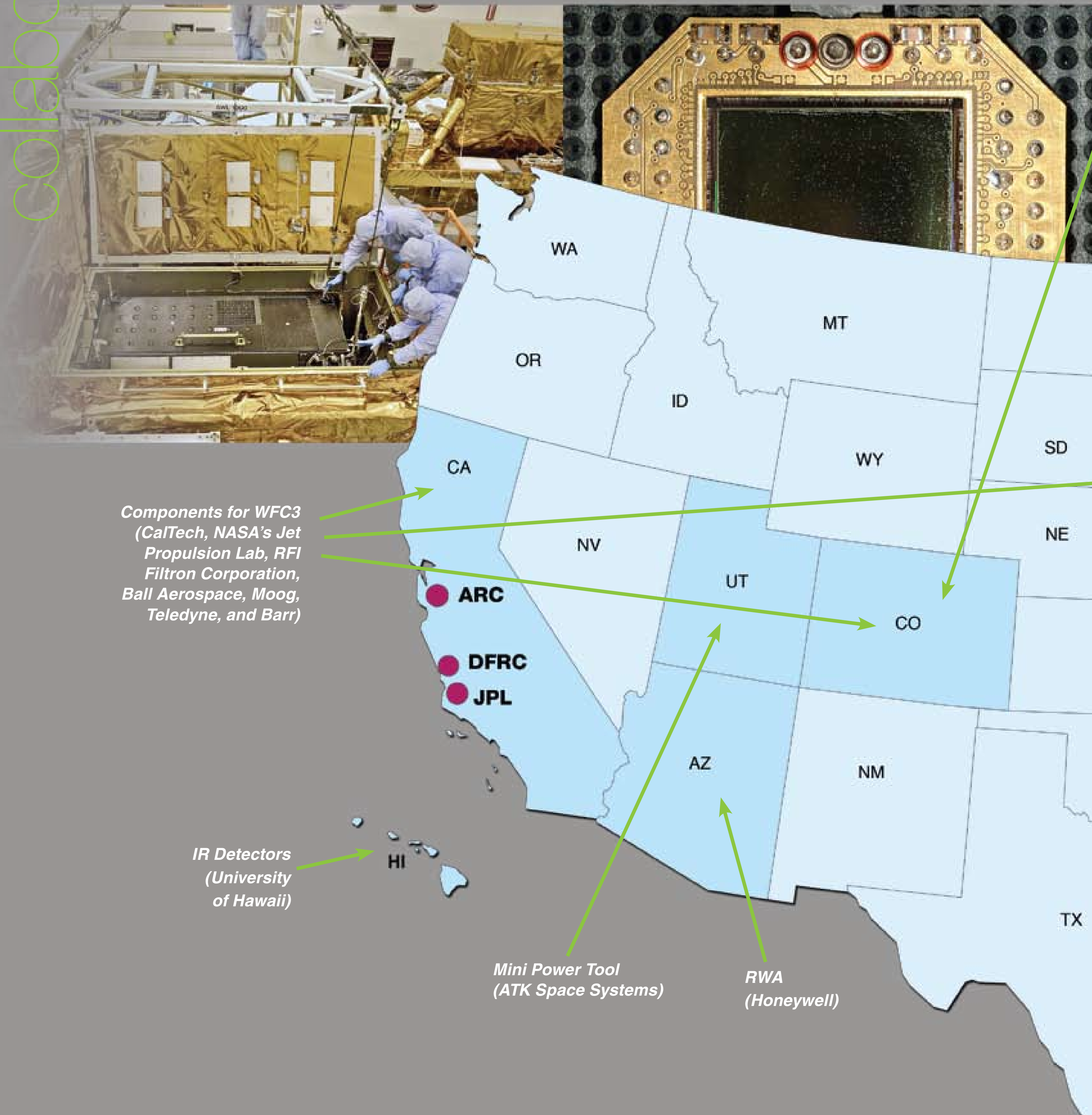
(continued on page 8)

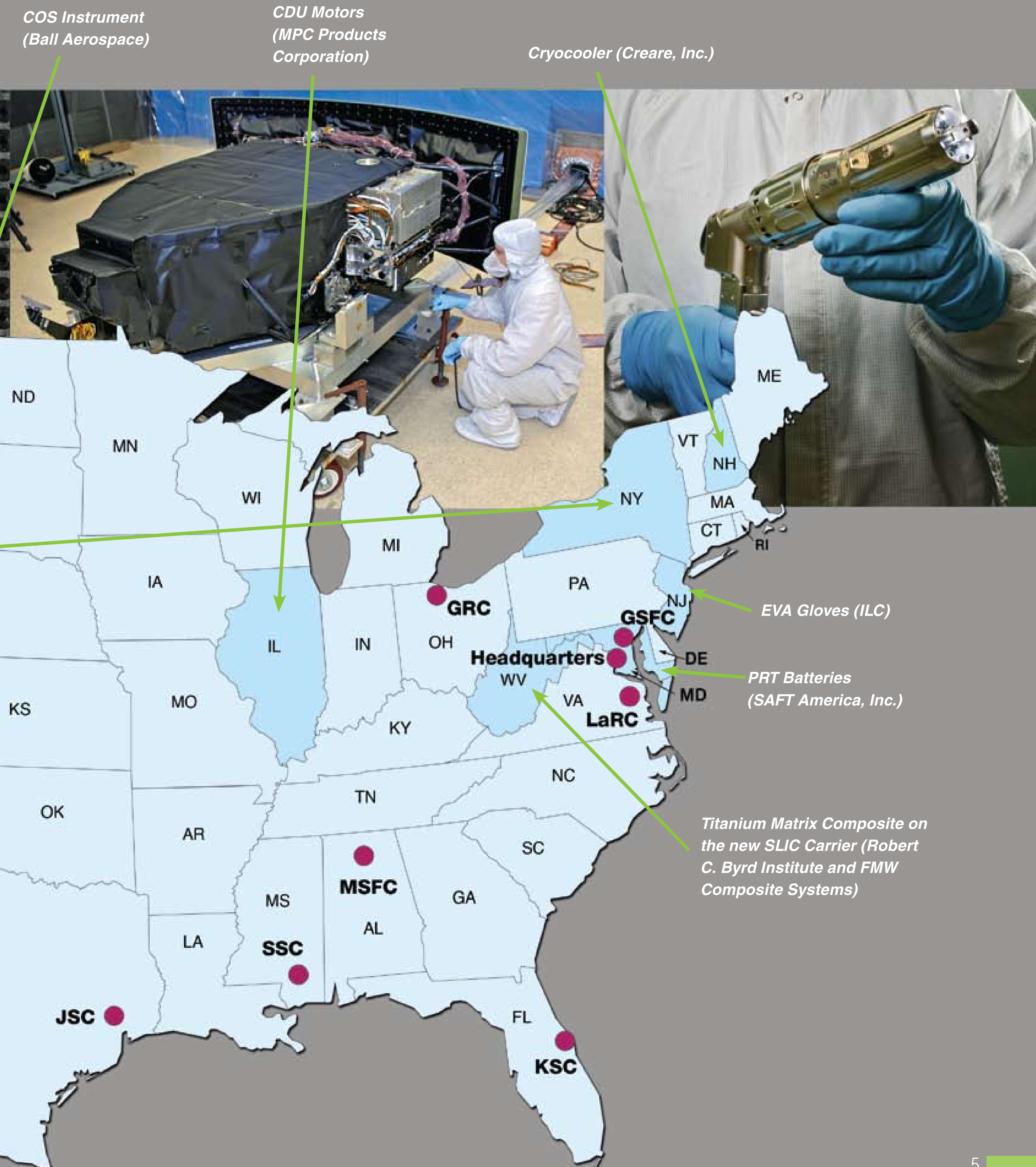
"With SpaceCube, we can get closer to 100 percent usage of data because we can process it in real time, compress it, and send it back to Earth."

— David Petrick, Team Lead, SpaceCube 1.0 Development Team

Contributions from Across the Nation

Companies and organizations in nearly every state in our nation have contributed to the Hubble Space Telescope Program through government research and development, contractor and supplier relationships, and other partnerships. This map shows some of the most significant contributions.




COS Instrument
(Ball Aerospace)
CDU Motors
(MPC Products
Corporation)
Cryocooler (Creare, Inc.)
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GRC
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Headquarters
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VA
LaRC
KS
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NC
TN
OK
AR
SC
MS
MSFC
GA
AL
LA
SSC
JSC
FL
KSC
EVA Gloves (ILC)
PRT Batteries
(SAFT America, Inc.)
Titanium Matrix Composite on
the new SLIC Carrier (Robert
C. Byrd Institute and FMW
Composite Systems)

Frank Cepollina

As Deputy Associate Director for the HST Development Project at Goddard, Frank Cepollina has become known as the "Father of On-Orbit Servicing" for his decades of leadership in repairing and upgrading satellites in orbit. On the eve of the final HST servicing mission, Cepollina talked to Goddard Tech Transfer News *about his decades of work on Hubble and plans for the future.*

"Astronauts are performing delicate, intrinsic tasks that are difficult to do even on the ground. It's an eye-opening mission. We should make new discoveries like none HST has ever seen before.

— Frank Cepollina, Deputy Associate Director, HST Development Project"

The Hubble—and your work on it—has quite a legacy. Can you share some of your most memorable experiences over the course of your many years working on HST?

The work toward on-orbit servicing of HST has really been memorable and rewarding since the very beginning. I've been working on HST since the early seventies. Back then, it was formally called the "large space telescope." I was involved from the beginning, in the first architectural concept whereby a telescope the size of HST could take advantage of the new capabilities of the shuttle system in terms of being able to take hardware up, repair on orbit, and bring hardware back down. The idea of fixing something in space excited me like nothing else. I grew up on a farm, and my job as a farm boy was fixing tractors and keeping machinery running. And I enjoyed it. So, in a sense, I've been "Mr. Fix-It" for quite some time. I still have a whole model railroad in the basement of my house and I belong to the Train Collector's Association. Tinkering around, fixing the trains with my kids… I've always enjoyed that. So, when the opportunity for something this challenging (on-orbit fixing) knocked, it took about ten seconds for me to say yes.

But this radical idea of on-orbit servicing was just a concept study in the seventies. In fact, most people thought it couldn't be done. Servicing a satellite in space seemed like a long shot and not too many people would listen to us. But we're a science center, and we hold fast to the proposition that we will use all possible tools to fly technology and capture new science and new discoveries of the universe. We had this golden opportunity to take advantage of the unique capabilities of the space shuttle—and we simply weren't going to be told we couldn't do it. And lo and behold, it happened. On-orbit serviceability became a reality.

What did you need to achieve from a technology perspective to make on-orbit servicing viable?

Well, the most important thing is that the spacecraft being serviced must be modular. This is what lets us go up, fix some parts on-orbit, replace parts with new technology, and take some sick parts home—rather than having to bring the whole spacecraft back to Earth. So developing the architecture for a serviceable Multimission Modular Spacecraft was key. And we proved how this could work with Solar Max [the Solar Maximum Repair Mission] in the early eighties. The servicing worked beautifully. That mission was certainly a highlight because it signified the capability of the space program to be able to support science in orbit. It represented significant support of human exploration and human endeavor. If it hadn't been for the repair of Solar Max, we would not be repairing HST in space today, or any of the other telescopes we repaired before HST. The realization of humans working in space with brand new systems, and repairing and replacing older systems was momentous. It changed the course of science and the course of my life.

Do any of the previous HST servicing missions stand out?

Certainly the most notorious was the first repair mission of HST. This stands out in my mind because of the timing. We had lost the

Challenger the year before. The press was questioning the agency. Our reputation was at stake. So that first repair mission required extreme ingenuity, persistence, and an insistence on getting it done right. At times, we were working in an arena of incredibility that we couldn't imagine tackling. That was the first step in dealing with the difficulty of on-orbit repair and maintenance—getting through the fear. Once we saw what we could do on orbit with SM1, the fear of failure disappeared and we employed more and more opportunities and technologies to solve problems. And here we are today, having launched SM4, which is above all the most complicated mission—from a servicing perspective—that the agency has ever flown. Astronauts are performing delicate, intrinsic tasks that are difficult to do even on the ground. It's an eye-opening mission. We should make new discoveries like none HST has ever seen before.

How do you and your team approach the challenges that go hand in hand with HST servicing?

First, you have to acknowledge that this work is not sugar and gravy. Every mission that we've done has progressed technologically—but it's progressed with gut-wrenching failures. You have to pick yourself and your team up with solid determination so that you don't let the failures bear down on you psychologically. You have to remember that disappointment is part of invention and part of discovery. Only through these challenges can you arrive at success.

So what is your work with the HST team like on a day-to-day basis?

Being a project manager is a great lesson in psychology. The key is learning how to keep your team motivated through tough challenges and to keep everyone moving forward. You have to walk around. You have to get out of your office. You have to keep visibility with your workers so they know you're there, they know you're behind them. Being a walk-around manager is the way I like to operate. I do paperwork, but I do it at home. I want to keep interfacing with my team. But sometimes, they lead me. The intelligence of the people on this team is remarkable and has really been the miracle of HST. They are motivated by the challenges we face, just as much as I am.

And what about working beyond your own team? How has technology transfer or infusion played a role in your work on HST?

It plays a huge role. First of all, HST servicing is all about technology. The technologies we've flown on the servicing missions so far have increased HST's power generation by 50%, and it has made the telescope about 30% more efficient. And SM4 is adding more power and huge increases in imaging sensitivity. Scientific discovery is synonymous with innovation and persistence, and the freshness of the technology you take to orbit. HST is not the same telescope it was in 1990. It's a new telescope every 3 to 5 years because every servicing mission, one after the other, deals with brand new, fresh technology. To make this happen, we have to take what's on the ground and adapt it for orbit. This often involves collaboration beyond our team. For example, for SM4, we wanted to fly so much technology that we would have exceeded the capacity of the carrier by about 2,000 pounds. Rather than accept that fact, we designed a super lightweight carrier, using all composite and struts made of Titanium Matrix Composite (TMC). The new carrier saved us over 1,500 pounds, and it was made possible through collaboration with Robert C. Byrd Institute in West Virginia and FMW Composite

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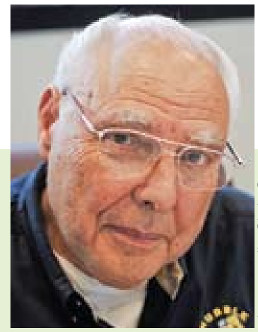


photo credit: Chris Gunn

Frank Cepollina

code: **442**

years with NASA: **46**

field of research:
On-orbit servicing

birthplace:
Oakland, CA

education:
BS, Mechanical Engineering, University of Santa Clara, CA

sbir/sttr

SBIR and STTR Programs Contribute to HST Technologies

Over the years, NASA's Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs have produced contracts resulting in mission-ready technologies for HST servicing missions. The examples that follow illustrate another way in which collaboration beyond NASA is helping to make textbook-changing scientific discovery possible.

IPP's Jim Chern manages the SBIR/STTR program at Goddard.

Miniature Cryogenic Turboalternator

In 1992, a Phase 2 SBIR contract awarded to Creare, Inc. of Hanover, NH resulted in the Miniature Cryogenic Turboalternator. The technology enables construction of a small, efficient, vibration-free cryocooler that can be tailored to various missions' cooling requirements. A subsequent $13 million, multi-year Phase 3 contract resulted in the successful installation and operation of a 75 K cooler on HST's Near Infrared Camera and Multi-Object Spectrometer (NICMOS) instrument. For more information, visit: ***http://sbir.gsfc.nasa.gov/SBIR/Successes/ss/154text.html***

High-Gain, Sheared MCPs

A Phase 2 SBIR contract awarded to Pegasus Glassworks of Sturbridge, MA in 1990 yielded high-gain, sheared microchannel plates (MCPs). The technology is an imaging intensifier plate with low ion feedback, low dark counts, and high gain in a single MCP. It also features uniformity of response and gain across the plate. The innovation was used in the Multi-Anode Microchannel Array detectors in HST's Space Telescope Imaging Spectrograph (STIS), and also is being used in other HST instruments, including the Advanced Camera for Surveys (ACS) and the Cosmic Origins Spectrograph (COS). For more information, visit: ***http://sbir.gsfc.nasa.gov/SBIR/successes/ss/5-015text.html***

Space Portable SpectroReflectometer

NASA awarded a Phase 2 SBIR contract in 1989 to AZ Technology, Inc. of Huntsville, AL, resulting in the development of a Space Portable SpectroReflectometer (SPSR). This handheld instrument measures key thermal control properties of material surfaces during extra-vehicular activities. The company subsequently was awarded a Phase 3 contract by NASA's Marshall Space Flight Center to deliver a flight-qualified SPSR, compatible with Extravehicular Activity operations on the MIR space station, HST, and the International Space Station. For more information, visit: ***http://sbir.gsfc.nasa.gov/SBIR/successes/ss/073text.html***

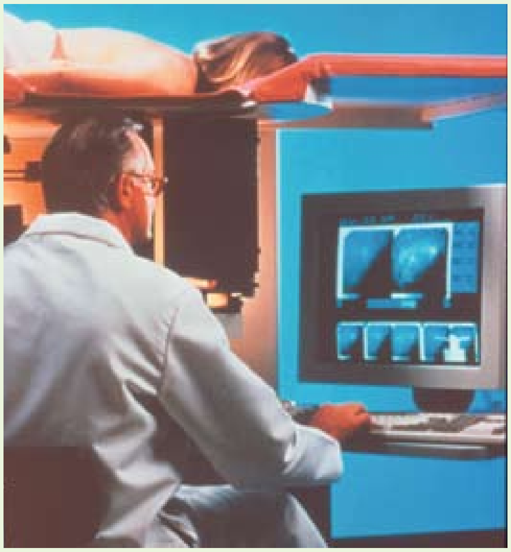
The SBIR/STTR programs at Goddard are administered by the Innovative Partnerships Program Office. For more information about how SBIR/STTR contracts help NASA achieve its mission and science goals, visit: ***http://sbir.gsfc.nasa.gov*** ■

SpaceCube *(continued from page 3)*

required. Although the system is not yet ready for mission-critical applications, it could be used in various high throughput data systems, UAVs, quick-launch sounding rockets, and commercial mini-satellites. Another advantage of the SpaceCube—that it is reconfigurable—may lead to humanitarian benefits as well. "We can quickly reprogram it to be an entirely different computer," said Petrick. "For example, we can reconfigure it to process data from surveys of Earth for ice or forest fires, or disaster-related events." And because SpaceCube makes better, faster use of more data in real time, scientists and other personnel will be better able to pinpoint locations to make life-enhancing and life-saving decisions. As the technology is further developed, the innovation team expects these commercial and humanitarian opportunities and benefits to increase as well. ■

HST Spinoffs Past and Present

The innovative technologies developed for the HST servicing missions have resulted in spinoffs beyond NASA, demonstrating uses in critical applications here on Earth. The following are just a few examples.



An imaging technology originally developed for HST was used to develop a less traumatic breast biopsy technique.

Breast Biopsy

An advanced, extra sensitive imaging technology called the Charge-Coupled Device—developed for HST by Scientific Imaging Technologies, Inc. (SITe) of Beaverton, Oregon—led to a non-surgical and much less traumatic breast biopsy technique in the early 1990s. The opportunity for technology transfer seemed clear because of the common requirements for astronomy and mammography: high resolution to see fine details; wide dynamic range to capture in a single image structures spanning many levels of brightness; and low light sensitivity to shorten exposures and reduce X-ray dosage.

The resulting technique replaced surgical biopsy as the method of choice in many cases, saving women time, pain, scarring, radiation exposure, and money. Known as stereotactic large-core needle biopsy, it is performed—under local anesthesia—with a needle instead of a scalpel, and it leaves a small puncture wound rather than a large scar. The procedure can be performed in a doctor's office instead of an operating room, and the imaging system also can be used for routine (non-biopsy) breast examinations.

Robotic Surgery

Robotics have been deployed and widely used on the space shuttle since the early eighties, supporting a variety of missions including Hubble servicing. Extra Vehicular Activities, supported by shuttle robotics, have continued to provide new leases on life to HST in orbit by replacing and upgrading key components and instruments on a regular basis.

One of the most notable new robotics technologies is the Special Purpose Dexterous Manipulator (nicknamed "Dextre")—a two-arm, "human-like" robot with a sense of touch that can perform many maintenance tasks. Only astronauts previously performed many of these, such as the removal and replacement of avionics and battery boxes. Dextre was launched in early 2008 and is planned to be fully operational via remote control from the ground in 2009. Dextre, selected in 2005 to become part of a robotic rescue mission for HST, also has serviced the International Space Station (ISS).

These advanced robotics and remote control capabilities have recently made their way into life here on Earth. Building on more than 30 years of shuttle/ISS robotics heritage, MacDonald Dettwiler and Associates (MDA) recently completed the development of NeuroArm, the world's first MRI-compatible surgical robot, capable of both microsurgery and image-guided biopsy. Based on the technology that powers Dextre, the surgical robotic system is controlled by a surgeon from a computer workstation, working in conjunction with intraoperative magnetic resonance imaging (MRI).

Robotics technologies that support extra vehicular activities were used to develop a human-like robotic arm for microsurgery and image-guided biopsies.

The technology allows a high-field MRI scanner to move into the operating room on demand, providing imaging during surgical procedures without compromising patient safety. Initial human clinical trials for the NeuroArm began in May 2008 and have been highly successful to date, underlining a successful transfer of technology from Space to Earth. ■

SM4 Technologies Flying Today May Be the Spinoffs of the Future

The fourth servicing mission (SM4) for HST, recently completed, offered an impressive set of advanced technologies that may yield remarkable discoveries and never before seen images of Earth, the solar system, and beyond. The technology list for SM4 included nearly 50 technologies, of which more than 20 are now being employed in orbit for the first time. Accomplishing SM4 goals will result in a complete rejuvenation of the 18-year-old HST, enhancing its capabilities with cutting-edge instruments as well as two intricate repairs. Many of the key technologies flown on SM4 for the first time also offer potential for spinoffs to Earth-based applications.

photo credit: Chris Gunn

The shuttle's new lightweight carrier, composed of Titanium Matrix Composite, offered nearly double the capacity of previous carriers.

New technology lowers weight to make room for more innovation

Achieving a lighter payload to accommodate more instruments on SM4 was the goal behind the shuttle's new super lightweight interchangeable carrier (SLIC), composed in part by another new technology—Titanium Matrix Composite (TMC). Offering nearly double the carrying capacity of previous carriers, SLIC's load included the new Wide Field Camera 3, new batteries, and other hardware and instruments, in excess of 3,000 pounds. Two of the six struts on SLIC are composed of TMC, which also was flown in space for the first time on SM4.

Spinoff potential: TMC already has been used on military jets and Boeing commercial aircraft. It is highly valued for offering greater stiffness, resistance against fracture, and lighter weight compared with alternative materials. In fact, the replacement of regular titanium with TMC resulted in a 20% reduction in weight and a 20% increase in strength for SLIC. In addition, the flight qualification of TMC on SM4 should enable use of the technology by other satellites and spacecraft in future NASA missions.

Advanced power tool aids repair

Repair of HST's Space Telescope Imaging Spectrograph (STIS) and Advanced Camera for Surveys (ACS) were highly intricate operations for astronauts to attempt on SM4. NASA's new Mini Power Tool (MPT), developed through a contract with ATK Space Systems and Jackson & Tull, aided the repairs. The MPT is a small, self-contained, battery-powered, hand-held device that also can be used as a non-powered manual wrench. Astronauts used the MPT to apply torque to various mechanical interfaces and fasteners. Detailed analyses of prior tools resulted in significant improvements over previous art. The design is highly ergonomic, to maximize in-hand comfort, reduce finger fatigue, and achieve precision positioning—all crucial concerns for highly intricate repair sessions that can last longer than four hours at a stretch. In addition, the design helps to ensure that the astronaut's "down the nose" view is free of obstruction, and an LED array delivers

A new Mini Power Tool was used to help repair HST's Imaging Spectrograph and Advanced Camera for Surveys.

illumination, both helping to maximize worksite visibility. The MPT also delivers unprecedented motorized torque capability for its size, thanks to its custom-designed, high-performance brushless DC motor in a 1-inch diameter housing. In addition, the MPT's unique modular design simplifies testing and assembly as well as on-orbit troubleshooting, because problems can be isolated to individual modules. The precise nature of this tool helped significantly to improve the likelihood that the critical repairs of STIS and ACS would be successful.

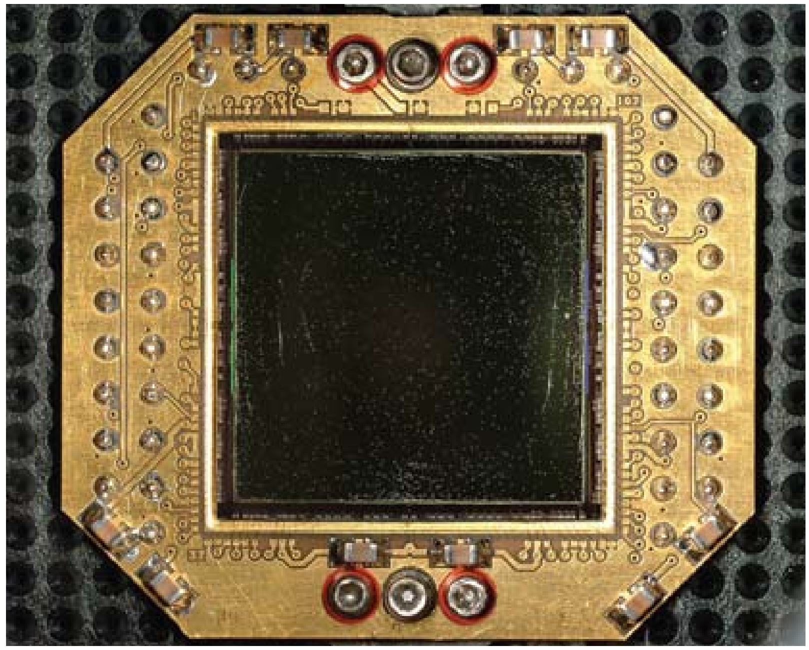


photo credit: Chris Gunn

New IR detectors on HST's Wide Field Camera 3 enable significantly more sensitive imaging.

New IR detectors help catapult imaging to new levels of sensitivity

In addition to HST's new Cosmic Origins Spectrograph (COS), the new Wide Field Camera 3 (WFC3) will enable a new era of discovery for HST. Compared with the previous imager, WFC3 is significantly more sensitive and boasts a much larger field of view, yielding infrared (IR) survey efficiencies 10-30 times greater than previously achieved. These advancements are made possible in part by new, cutting-edge Mercury-Cadmium-Telluride (HgCdTe) IR detectors. The technology is the result of a newly tailored composition of previously existing HgCdTe IR arrays to achieve a 1.7-micron wavelength cutoff.

The new composition eliminates the need for expendable cryogen or a complex mechanical refrigerator, because the detectors are able to run with very low, dark current at a temperature of 145K, achievable with a passive radiator and thermoelectric cooling. The detectors also are relatively insensitive to thermal radiation from HST's warm optics. These advantages result in better sensitivity for seeing very faint astronomical targets. The improvements to sensitivity and survey efficiency open the door to even more detailed studies of distant galaxies, mysterious dark energy, star formation, and detection of small bodies at the furthest reaches of our solar system.

 (continued from page 11)

photo credit: Chris Gunn

Three cameras on the new Relative Navigation System were used to estimate real-time attitude and positioning of HST during deployment and docking.

Relative navigation tested for new rendezvous capabilities

A new Relative Navigation System (RNS) also was tested on SM4, including three cameras and an avionics package to record images, and to estimate real-time attitude and positioning of HST relative to the shuttle during capture and deployment of the telescope. RNS's SpaceCube technology provided an advanced, new, reconfigurable space flight processor that can host all RNS pose, command, and data handling, as well as camera control software. Also key to RNS is GSFC's Navigator—an autonomous, real-time, fully space flight-qualified GPS receiver, with exceptional capabilities for fast signal acquisition and weak signal tracking. The technology gathered and forwarded composite raw data, processed data, and telemetry information, including inertial position and velocity, channel tracking, and estimated range from HST to the shuttle. The RNS system has completed extensive testing at NASA's Marshall Space Flight Center and may revolutionize rendezvous and docking operations in future NASA missions.

Spinoff potential: The Navigator is applicable to many high-altitude spacecraft (e.g., Geostationary Operational Environmental Satellite, Magneto Multiscale Science, other geostationary orbit satellites) as well as low Earth orbit spacecraft through enhanced GPS navigation. In addition, the relative navigation system as a whole may find application in commercial and military aircraft navigation.

Partnership Profiles

The IPP Office is pleased to announce the recent signing of several agreements.

Partner	Technology/Focus	Agreement Type	NASA Goals/Benefits
Harvard College Observatory	Refractive index measurements of partner-supplied optics at Goddard's Cryogenic High Accuracy Refractive Measurement System (CHARMS) facility	Reimbursable SAA	NASA will be able to add the refractive index data generated for the partner to publicly available optics data, providing an opportunity to improve optical designs for scientific instruments operating at cryogenic temperatures, without investing additional research funds to repeat such measurements.
ITT Space Systems	Photonic technologies	Reimbursable SAA	To expand the available selection of highly reliable photonic parts for spaceflight use, ITT will provide various laser diode components to Goddard for screening and qualification testing. The resulting data will be available to Goddard for potential application to future flight programs.
Department of Defense Operationally Responsive Space Office (ORS)	Multiple technology transfers to DoD	Reimbursable SAA	The agreement will enable Goddard to define how it will transfer technologies and capabilities, including enterprise ground system core components and interfaces, range safety and operations, platforms for launch vehicle and spacecraft applications, and management and system engineering support to ORS.
Office of Naval Research (ONR)	Development & Test of H4RG Read Out Integrated Circuit	MOU	Goddard and ONR wish to jointly develop and test Hawaii-4RG large format focal plane technology for utilization within their respective missions. Specifically, NASA will provide ONR up to 12 H4RG readout integrated circuits, then ONR will process these into fully functional detectors and arrange for performance and radiation effects testing. Test results will be shared between the organizations.

SAA = Space Act Agreement
MOU = Memorandum of Understanding

Innovator insights *(continued from page 7)*

Systems, the company that manufactures the TMC. And that technology also is making its way into commercial applications. FMW is taking it to Boeing, and it will be flown on Boeing 787 aircraft. We've also had some HST technologies make their way into medical applications and other uses. So, often, it comes full circle.

Editor's Note: For more information about these HST technology spinoffs, see the story on page 10.

SM4 was the last scheduled mission to service Hubble. So, what are your plans for the future?

If NASA has a challenge as great as HST, I'll be on board with solving it. It's the technological challenge. It's the ability to get in there and do the impossible. But if something on the order of HST doesn't come up, it will be time for something new. Am I going to retire? Well, I don't think I'll ever really retire until I start looking up at the daisies. But I will do something else. I'm not sure what just yet, but I have some ideas. As long as I'm staring down a big challenge, I'll be just fine. ■

Bringing HST to the Apex of its Capabilities for Science

"The Hubble Space Telescope is arguably the most powerful single optical astronomical facility ever built. Hubble provides wavelength coverage and capabilities that are unmatched by any other optical telescope currently operating… Hubble is a uniquely successful NASA science program and is a national asset well worth maintaining in operation." This is according to an NAS Panel Report, published in December 2004.

This photo taken by Hubble shows Arp 274, a trio of galaxies. They appear to be partially overlapping in this image but may be located at different distances.

photo credit: Chris Gunn

David Leckrone, HST Senior Project Scientist

Indeed, the in-orbit maintenance and technology upgrades that have been the cornerstones for all HST servicing missions have enabled remarkable scientific discoveries that changed the content of science textbooks and the course of astrophysical and astronomical research. The key HST discoveries most often cited to date include:

- Understanding how the galaxies were formed
- Determining that the expansion of the universe is speeding up
- Calculating the distance scale and age of the universe
- Detecting giant black holes in the nuclei of galaxies
- Understanding the highly energetic nuclei of active galaxies
- Measuring the properties of the intergalactic gas from which galaxies formed
- Elucidating the chemical properties of the interstellar medium from which stars formed
- Locating sources of gamma ray bursts in distant galaxies
- Detecting and determining the structure of protoplanetary disks
- Detecting and measuring the composition of the atmospheres of extrasolar planets

According to HST Senior Project Scientist David Leckrone, half of these discoveries were unanticipated. Leckrone attributes this to the broadly capable technologies applied to HST via the servicing missions. "The more robust the technology, the more likely surprises will accompany anticipated discovery," Leckrone said. He noted that the SM4 technologies and the recent repairs to the telescope will bring Hubble to the apex of its scientific capabilities, resulting in the most influential scientific discoveries to date—both expected and unknown. Among the most notable areas of anticipated discovery are the following.

The Life Story of Galaxies

WFC3, ACS, and COS combined will enable deeper study and understanding of how galaxies formed and have changed over time, according to Leckrone. The course of galaxy evolution over the last 13 billion years will help NASA scientists understand more about how we arrived where we are and what evolution has in store for our galaxy and others. Infrared detectors currently flying on SM4 will enable IR ultra-deep fields of imaging, helping to provide information about the universe when it was less than a billion years old. In addition, COS is expected to provide more information about the chemical evolution of galaxies, while the critical repair of STIS will enable the study of super massive black holes at the centers of galaxies and what impact they have on galaxy structure and evolution.

The Architecture of the Universe

NASA scientists know that the architecture of the universe, or the Cosmic Web, is not smooth, but rather made of areas of density and areas of void. But the distribution of matter is not well understood today. Leckrone noted that the advancements made to HST through the

Hubble photo of
the Eagle Nebula

recent servicing mission promise to change that. COS will study this architecture on both a large scale (measuring how the gravity of dark matter has assembled the intergalactic gas into the web-like structure we see today) and a small scale (detecting the interactions between individual galaxies or clusters of galaxies and the intergalactic medium). In just a few weeks of observation, COS will probe more of the Cosmic Web than all previous HST spectrographs combined.

Birth and Death of Stars

The birth, formation, and death of stars and what this information means for the overall evolution of galaxies is another area of great interest with expected advances in discovery following SM4, Leckrone said. "Scientists know that as a star dies, the material in its nucleus is given off and becomes a part of the next generation of stars," Leckrone said. "After this servicing mission, WFC3, ACS, and COS will further study how that material contributes to star formation and how the evolution of stars has varied over time and over different galaxies." The technologies will also enable the study of supernovae and their remnants, and the origin of the elements composing stars and other objects.

The Mysteries of Dark Matter and Dark Energy

The optical and IR capabilities of WFC3 and ACS working in parallel will increase HST's discovery rate by about 2.5 times. Surveying the sky to find exploding stars (supernovae) used to measure distances to the galaxies in which the supernovae occur will enable scientists to measure more accurately how rapidly the universe was expanding at various points in time. This will provide additional clues about the nature of the "Dark Energy" that is causing the universe to expand at an accelerating pace. For example, is Dark Energy constant or has it changed in strength over time? "The structure of the universe is dictated by the gravity of dark matter, which we can't see," said Leckrone. "But we can detect its presence and distribution in space because the gravitational tug of dark matter bends and distorts the light coming from distant galaxies. These distortions can be observed in images taken with WFC3 and ACS. They allow scientists to map the distribution of "Dark Matter" in three dimensions."

Recipes for Building Planets

"Once STIS is repaired during the current servicing mission," Leckrone said, "scientists will once again use it to study the chemical composition of the atmospheres of extra-solar planets. The atmospheres of transiting planets (those that pass in front of their mother star) absorb light from the star, which can then be measured by STIS. The COS will also be used to attempt these difficult observations in ultraviolet light. "Ultimately, this may help us better understand the composition and structure of the atmospheres of distant planets," said Leckrone. "This is a great example of surprises yielded by Hubble. We never expected to be able to make these kinds of extra-solar planet observations with this telescope."

And as for other unknown areas of discovery, and other questions to explore? According to Leckrone, they are certainly possible—and par for the course. "One thing HST has taught us is that we shouldn't be surprised if we're surprised," Leckrone said. "Hubble has answered questions that we didn't even know to ask when we were just getting started." ■

Staff from IPP Office attended several events in Winter 2008/2009 and

At the Business Opportunities Through Tech Transfer event, Mike Hitch described the unique capabilities in unmanned vehicle experimentation available at the Wallops Flight Facility.

Wallops Flight Facility's Geoff Bland gave a presentation about "Unmanned Aircraft System Technology for Earth Science" at the Business Opportunities Through Tech Transfer event.

Midshipmen from USNA visited the AETD booth at Annapolis Space Day.

Licensing Executive Society (LES) Annual Meeting *(October 19, Orlando, FL):*

Attended training seminars about best practices regarding licensing and commercialization of intellectual property including software. Made contact with a variety of experts and representatives from the technology transfer and licensing industry.

American Evaluation Association *(November 5-6, Denver, CO)*

Gained insight into the breadth and depth of the field of evaluation—from exploration of traditional and emerging methodologies to addressing issues related to working internationally and cross-culturally, and to delving into applications of evaluation in a range of disciplines. Technology Transfer Manager Darryl Mitchell spoke about Goddard's auction of exclusive licenses for federally owned patents through a live auction process with Ocean Tomo.

2008 SBIR National Conference *(November 12, Hartford, CT)*

Participated in a NASA exhibit; held one-on-one discussions with current and potential SBIR/STTR companies about new business opportunities; and participated in presentations relevant to the NASA IPP Program and priorities.

Nanotech Briefs Conference *(November 12, Boston, MA)*

Gained insight into current and future developments in engineering innovations at the nanoscale level, as well as the commercialization of nanotechnology.

Mid-Atlantic Innovation Showcase *(November 14, Tysons Corner, VA)*

Highlighted new technologies available for license and showcased technology transfer opportunities in discussions with industry partners, fellow innovators, venture capitalists, and colleagues from the region.

Spring 2009

Technology Transfer Manager Ted Mecum met with attendees at the Business Opportunities Through Tech Transfer event.

(From left to right) Irene Tzinis, Ted Mecum, and Nona Cheeks pose with Henry Wixon, Co-Chair of the Maryland Chapter of the LES, who was honored for his service at the Maryland LES Chapter Meeting.

Maryland Licensing Executive Society (LES) Chapter Meeting *(November 19, Greenbelt, MD)*

Hosted more than 40 guests from federal labs as well as intellectual property and technology transfer organizations, and featured guest presenter Victoria Espinel, Assistant Professor of International Trade at George Mason University, who spoke about "IP and American Competitiveness."

American Intellectual Property Law Association *(January 28, Miami, FL)*

Gained practical advice from experienced in-house and outside IP counsel on topics including new prospects for U.S. patent reform, international IP enforcement, and global branding strategies.

Business Opportunities through Tech Transfer *(January 29, Salisbury, MD)*

Participated in networking opportunities at this event, sponsored by the Mid-Atlantic Federal Laboratory Consortium, which featured panels of experts discussing technologies from universities, economic development groups, and federal agencies as well as a NASA panel with speakers from NASA's Wallops Flight Facility.

Annapolis Space Day *(February 12, Annapolis, MD)*

Provided an IPP exhibit and information about the State's communications and business connections with Goddard.

Project Management Challenge *(February 24, Daytona Beach, FL)*

Gave two presentations, "Forming Innovative Partnerships to Enhance Future Mission-Enabling Capabilities" and "The Technology Transfer Lecture," and hosted an agency-wide IPP exhibit at this premier training event.

47th Robert H. Goddard Memorial Symposium *(March 10, Greenbelt, MD)*

Joined NASA and industry experts to discuss new business leads and technology priorities. ■

IPP Staff members, Dale Clarke, Irene Tzinis, and Melissa Jackson interact with Girl Scouts at Annapolis Space Day.

NASA Inventions and Contributions Board Awards

The following awards were issued by ICB during the first and second quarters of FY09.

Tech Briefs Awards

A Method And System For Formal Analysis, Simulation, And Verification Of Knowledge-Based Systems, Rule-Based Systems, And Expert Systems by Denis Gracanin and John Erickson (both Code 588)

HDF-EOS2 And HDF-EOS5 Compatibility Library by John Bane, Jinglie Yang, and Richard Ullman (all Code 586)

Spatial and Temporal Low-Dimensional Models for Fluid Flow by Virginia Kalb (Code 600)

A Diamond Machined, Freeform Mirror For Near-IR Astronomy by Alex Sohn (Code 551)

HDF-EOS Web Server by John Bane, Jinglie Yang, and Richard Ullman (all Code 586)

Direct Solve Image Based Wavefront Sensing by Richard Lyon (Code 600)

HDF-EOS5 Validator by John Bane, Jinglie Yang, and Richard Ullman (all Code 586)

Pseudo Diversity-Direct Wavefront Control with Image Restoration at High Bandwidth by Richard Lyon (Code 600)

HDFEOS XML DTD And Schemas by Jinglie Yang and Richard Ullman (both Code 586)

XML To HDF-EOS Convertor by John Bane, Jinglie Yang, and Richard Ullman (all Code 586)

Aquarius Digital Processing Unit by Norman Dobson (Code 603), Gregory Winkert (Code 564), and Joshua Forgione (Code 564)

The Turbotrap by John Lorenz and John Keller (both Code 691)

Compact, Low-overhead MIL-STD-1553B Controller by Richard Katz (Code 564)

Compact Reliable EEPROM Controller by Igor Kleyner and Richard Katz (both Code 564)

Three-Dimensional Range Imaging Apparatus and Method by James Blair, Luis Izquierdo, and Vibart Scott (all Code 694)

Software Release Awards

Direct Solve Image Based Wavefront Sensing by Richard Lyon (Code 600)

Goddard Mission Services Evolution Center (GMSEC) Criteria Action Table (CAT) by John Bristow (Code 581)

Goddard Mission Services Evolution Center (GMSEC) GMSEC Environmental Diagnostic Analysis Tool (GEDAT) by Allison Greene (Code 584)

GPM Software by Liang Liao, Matthew Schwaller, and Kenneth Morris (all Code 581)

GMSEC System Agent by John Brisow (Code 581), Christopher Shuler (Code 584), Brian Gregory (Code 583), and Chiu Yeung (Code 581)

GMSEC ANSR by Joseph Gurganus, Everette Cary, and Eobert Antonucci (all Code 583)

GMSEC CAT 5.0 by Robert Wiegand and Chiu Yeung (both Code 583)

GMSEC Architecture API [R3] 2.5 by Waka Waktola, Voung Ly, Robert O'Brien, Eric Martin, and Rick Woods (all Code 583)

Method For Implementation Of Recursive Hierarchical Segmentation On Parallel Computers by James Tilton (Code 606)

DSIL Communications Adapter Set by Carola Ugarte, Kimberly Hawkins, Thomas Jackson, Jacob Hageman, and Gerard Cote (all Code 582)

Pseudo Diversity-Direct Wavefront Control with Image Restoration at High Bandwidth by Richard Lyon (Code 600)

GPM Software by Matthew Schwaller and Kenneth Morris (both Code 581)

Space Act Awards

Goddard Mission Services Evolution Center Message Bus (GMSEC MB), R2 by Arturo Mayorga (Code 581)

Goddard Mission Services Evolution Center Architecture Application Programming Interface (GMSEC Architecture API) [R2] by Mike Butschky (Code 583), Waka Waktola (Code 583), Christopher Shuler (Code 584), Brian Gregory (Code 583), and Eric Martin (Code 583)

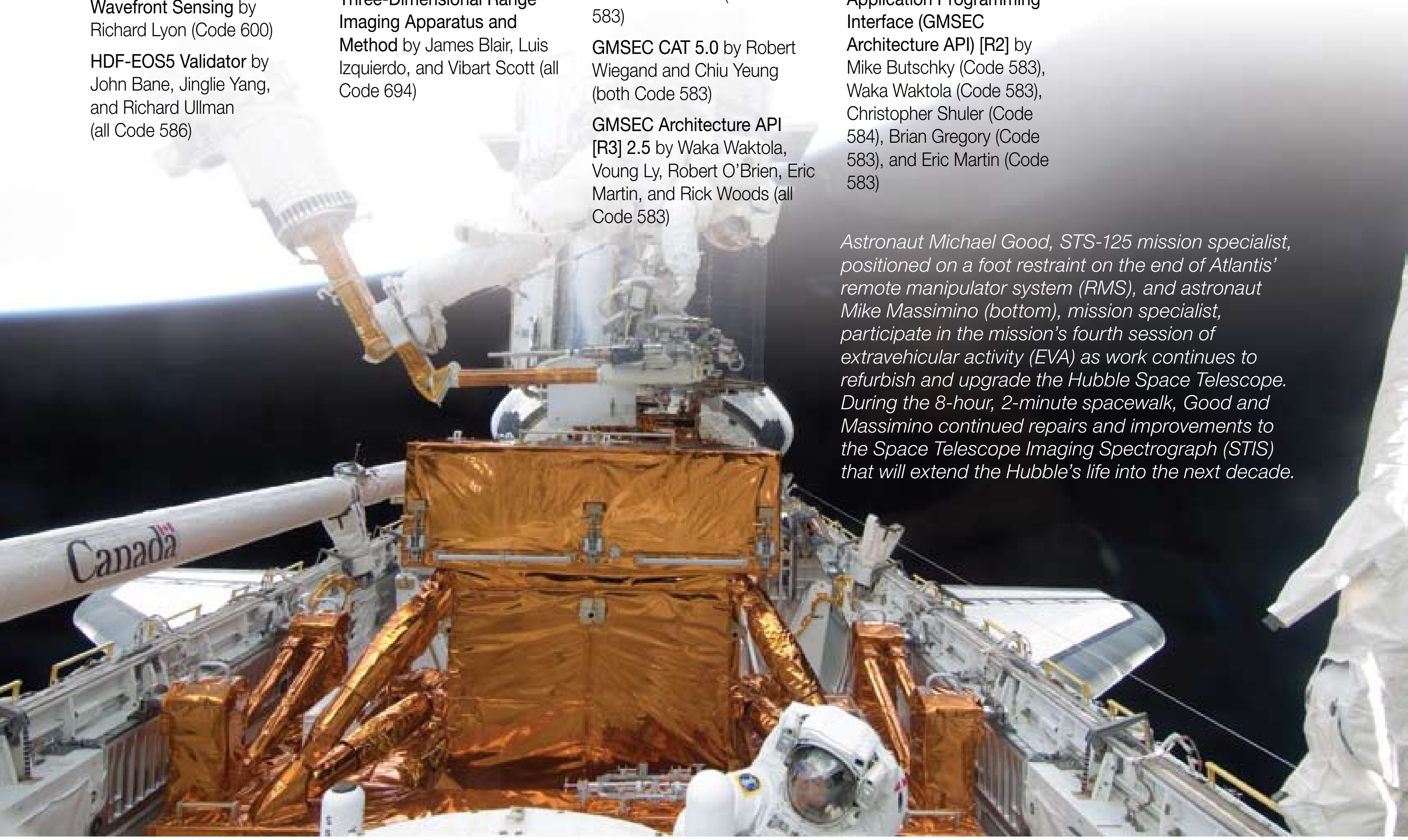
Goddard Mission Services Evolution Center (GMSEC) Architecture, R2 by Danford Smith (Code 581), Thomas Grubb (Code 583), and James Fessler (Code 581)

Direct Solve Image Based Wavefront Sensing by Richard Lyon (Code 600)

Method And Apparatus For Second Harmonic Generation And Other Frequency Conversion With Multiple Frequency Channels by Jeffrey Chen (Code 554)

Goddard Mission Services Evolution Center Message Bus (GMSEC MB), R2 by John Bristow (Code 581)

Ultra Lightweight Active Optics For Space Observatories Technology Program by Lee Feinberg (Code 442), and David Jacobson, H. Stahl, Richard Burg, Bernard Seery, Ritva Keski-kuha, and J. Russell (all Code 440) ■



Astronaut Michael Good, STS-125 mission specialist, positioned on a foot restraint on the end of Atlantis' remote manipulator system (RMS), and astronaut Mike Massimino (bottom), mission specialist, participate in the mission's fourth session of extravehicular activity (EVA) as work continues to refurbish and upgrade the Hubble Space Telescope. During the 8-hour, 2-minute spacewalk, Good and Massimino continued repairs and improvements to the Space Telescope Imaging Spectrograph (STIS) that will extend the Hubble's life into the next decade.

Tech Transfer Metrics First and second quarters of FY09.

New Technology Reports: 64

12-meter Deployable Shroud for the International X-ray Observatory by David W. Robinson (Code 543)

Goddard Mission Services Evolution Center Architecture Application Programming Interface (GMSEC Architecture API) 2.6 by SRA/ICS

Ensemble Statistical Analysis by Paul Racett (Code 555)

Ensemble Detector by Paul Racett (Code 555)

Early Oscillation Detection Technique for Hybrid DC/DC Converters by Perot Systems

Core Flight Software System (CFS) Data Storage Application Version 1 by SSI

3D Plasma Ion Composition Spectrometer (3DPICS) by Edward Sittler (Code 673)

3D Dual Tophat Ion Neutral Mass Spectrometer by Edward Sittler (Code 673)

High Precision Electric Gate (HPEG) for Time of Flight Mass Spectrometers by Edward Sittler (Code 673)

Bonded Invar Clip Removal Using Foil Heaters by James Pontius (Code 542)

Hybrid Architecture Active Wavefront Sensing and Control by Bruce Dean (Code 550)

Gratings fabricated on flat surfaces and reproduced on non-flat substrates by LightSmyth Technologies

JDataDownloader, a Java based tool for downloading online data by Adnet Systems, Inc.

Core Flight Software System (CFS) Housekeeping Application Version 1 by SSI

SpaceCube 2.0 an Advanced Hybrid On-Board Data Processor by Tom Flatley (Code 587)

The Invasive Species Forecasting System—Architecture and Operation by INNOVIM

The Invasive Species Forecasting System—Framework by INNOVIM

The Invasive Species Forecasting System—Command Interpreter (iShell) by INNOVIM

The Invasive Species Forecasting System—Core Services (iCore) by INNOVIM

The Invasive Species Forecasting System—Predictors/GSENM by INNOVIM

The Invasive Species Forecasting System—Programs/SWLR by INNOVIM

The Invasive Species Forecasting System—Applications/QuickMap by INNOVIM

Experiment in On-board Synthetic Aperture Radar Data Processing, with Radiation Hardening by Software, on Tilera Multicore Processor by Matt Holland (Code 587)

Unified Incident Command and Decision Support (UICDS) by SAIC

Micro-channel Embedded Pulsating Heat Pipes by Peregrine Falcon Corp.

WATS: Wind and Temperature Spectrometry of the Upper Atmosphere in Low-Earth-Orbit by Fred Herrero (Code 553)

Core Flight Software System (CFS) Scheduler Application Version 1 by The Hammers Co.

Core Flight Software System (CFS) File Manager Application Version 1 by Maureen Bartholomew (Code 582)

Core Flight Software System (CFS) Limit Checker Application Version 1 by Maureen Bartholomew (Code 582)

Goddard Mission Services Evolution Center (GMSEC) SystemAgent 2.0. by Chiu Yeung (Code 585)

Step Doublet Algorithm for Reduction of Stepper Motor Induced Jitter by NightSky Systems

Development of Ethernet PHY circuit from individual discrete components for rad-hard environments by MicroSat

High performance data analysis tools for Sun-Earth connection missions by Tech-X Corp.

Application Controlled Parallel Asynchronous Input/Output Software Utility by Northrop Grumman

Core Flight Software System (CFS) Stored Command Application Version 1 by Maureen Bartholomew (Code 582)

Propellant Tank Pressurization Modeling for a Hybrid Rocket by Margaret Anderson (Code 548)

Optimizing Automated Interference Mitigation Scheduling Method and Algorithm by James Rash (Code 580)

Visual System for Browsing, Analysis and Retrieval of Data (ViSBARD) by Aquilent, Inc.

Event-Driven Readout of Active Pixel Detectors by Penn State University

Single Frequency High Peak Power Fiber Amplifier For Spectroscopy by Lockheed Martin

Ground and space radar volume matching and comparison software by SAIC

Miniature Spherical Mirror Mount by Raytheon

Agora: A Comprehensive General-Purpose Simulation of Attitude and Trajectory Dynamics and Control of Multiple Spacecraft by Eric Stoneking (Code 591)

Crossed Small Deflection Energy Analyzer (SDEA) for Wind/Temperature Spectrometer (WTS) by Fred Herrero (Code 553)

Automatic Extraction of Planetary Image Features by University of Iceland

Core Flight Software System (CFS) Checksum Application Version 1 by Maureen Bartholomew (Code 582)

Core Flight Software System (CFS) Memory Dwell Application Version 1 by Maureen Bartholomew (Code 582)

Visualization in Real-Time Experiment (VIRTEx) by Ben Cervantes (Code 581)

Link Analysis in the Mission Planning Lab (MPL) for Wallops Flight Facility by Jessica McCarthy (Code 598)

Maskless Creation of Small Structure with Selective Deposition of Gold Nano-particles (Gold Black) by Brooke Lakew (Code 693)

Orbit Determination Toolbox by Emergent Space Technologies

Novel Superconducting Transition Edge Sensor Design by John Sadleir (Code 662)

Nanostructure diffraction spoiler by John Hagopian (Code 551)

Passively Q-switched side pumped Monolithic Ring Laser by Stephen Li (Code 554)

An All-metal, Solderless Circularly Polarized Microwave Antenna Element with Very Low Off-Axis Cross-Polarization by MEI Technologies

XTCE ToolSet by Global Science and Technology, Inc.

Core Flight Software System (CFS) Memory Manager Application Version 1 by Maureen Bartholomew (Code 582)

Mercury Software Toolset for Spatiotemporal Metadata by UT Battelle

A Novel Precipitation Radar System by Remote Sensing Solutions

V3—A secure web-based gateway for content management and the tools commonly needed for communicating project information by CSE

OPTOOL: General Purpose Optical and Radiometric Modeling Software by KDA Engineering

Small Bolt Torque Tension Tester by Alan Posey (Code 543)

Novel Design Concepts for Compact Low-Loss Multi-Path-Interference Suppressed All-Fiber Gas Cells Using Hollow-Core Fibers by Maryland University

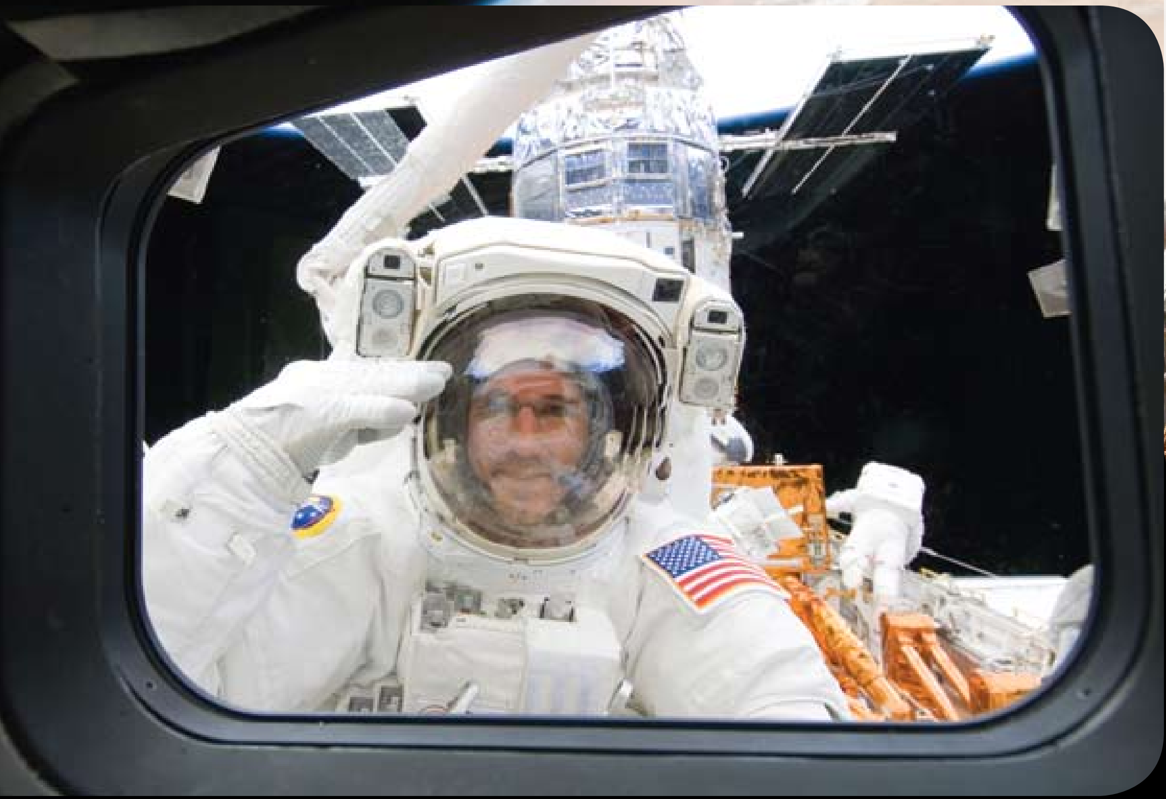
An Architecture for a 1GHz Digital RADAR by Udayan Mallik (Code 564)

Patent Applications Filed: 1

Tooless Assembly Design For Composite Corrugated Feedhorns by John Marks (Code 543)

Hubble Space Telescope
Servicing Mission 4

Astronauts John Grunsfeld (bottom) and Andrew Feustel in one of several STS-125 extravehicular activities to perform work on the HST.



While standing on the end of Atlantis' remote manipulator system arm, astronaut Michael Good, STS-125 mission specialist, pays tribute to his commander and all his crewmates with a military-style salute. Astronaut Good and mission specialist Mike Massimino (working in the background at right) were locked down in the orbiter's cargo bay as they worked on the HST during the recent servicing mission.

Goddard Tech Transfer News **http://ipp.gsfc.nasa.gov**

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